Establishment of Brachiarias Intercropped with Maize

Estabelecimento de Braquiárias em Consórcio com Milho

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Resumo

O consórcio de gramíneas forrageiras com o milho pode ser utilizado tanto para renovações de pastagens, como para a formação de cobertura morta de qualidade e longevidade para o sistema de Plantio Direto. O objetivo deste trabalho foi avaliar, em um sistema de consórcio com a cultura do milho, o desempenho de diferentes espécies de braquiárias quando da fase de estabelecimento, bem como a adequação dessas espécies para o referido sistema. O experimento foi conduzido em Nitossolo eutroférrico típico, sob pivô central, em área experimental na Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, situado no Município de Piracicaba, SP. O delineamento experimental utilizado foi o de blocos ao acaso com sete tratamentos e quatro repetições. Os tratamentos foram constituídos da combinação de três espécies de braquiárias (*Brachiaria decumbens*, *Brachiaria brizantha* cv. Marandu e *Brachiaria ruziziensis*), semeadas em duas épocas (concomitantemente ao milho, e quando o milho apresentava quatro folhas totalmente expandidas), acrescido de um tratamento testemunha (milho solteiro). Todas as espécies semeadas na primeira época (semeadura concomitante ao milho) diferiram daquelas semeadas quando o referido cereal apresentava quatro folhas, quanto à produção de massa verde e seca. O genótipo *B. decumbens* se destaca quanto ao duplo propósito de supressor de plantas daninhas e produção de forragem.

Palavras-chave: Brachiaria. Competição. Milho. Consorciação. Integração. Sistemas de Produção.

Abstract

Grasses intercropped with maize can be used both for pasture renewals and for quality and longevity of soil cover formation in no-tillage crop systems. The present study aimed to evaluate, under the intercropping with maize perspective, the performance of three different genotypes of Brachiaria during establishment stage, as well as the suitability of those in the mentioned production system. The experiment was carried out in Piracicaba, São Paulo State, Brazil (Universidade de São Paulo, ESALQ), in a typical Rhodudalf soil, under the centre pivot irrigation area of Crop Science Department. The experimental design was in randomized blocks with seven trails and four replications. The trails consisted of a combination of three Brachiaria species (Brachiaria decumbens, Brachiaria brizantha Marandu and Brachiaria ruziziensis) sowed in two different dates (together with maize and when maize had four fully expanded leaves), as well as a control trail (single maize). All grasses sowed on the first date (concomitantly sowed with maize) have differed from those sowed when maize presented four completely expanded leaves, in terms of green and dry matter productivity. Genotype B. decumbens can be highlighted if the intention is both to control weed growing and to produce forage.

Keywords: *Brachiaria. Competition. Zea mays L.. Intercropping. Mix Farming. Agricultural Systems.*

1 Introduction

The consolidation of a sustainable and profitable agriculture depends upon the recognition of ecosystem fragility when society decides to modify it towards to develop agriculture. Thus, it is reasonable to employ suitable methods and technologies i, as well as to create new agricultural alternatives based on both systemic focus and rational agronomic practices that can help establishing a desirable and specific agriculture. Currently, Brazilian agriculture is very developed as a business and spread inland on country in well rainfed areas, where it is normally achieves figures such as 1,500 mm a year distributed in seven or eight months, being the remnant ones predominantly drier. It is worthwhile to outline the existence of high temperatures in those areas so that it is not an easy task to maintain the level of organic matter of agricultural crop soils.

In fact, this contributed to a no-tillage systems proliferation and a corresponding necessity to develop new methods of cropping, appropriated to local conditions at a large scale or industrial farm level. Moreover, the increasing preoccupation towards reducing the use of water and pesticides associated with competitiveness in time and space, which are, indeed, required to successfully promote economical sustainability, has largely emerged methods like crop rotation contemplating non-trading crops (so-called "green fertilisers"), no-tillage systems, intercropping, mixed farm systems (i.e. contemplating animal production) and those in which grasses generally utilised in animal production are used as rotation and mulch formation (Lamas and Staut, 2005).

In some places of Brazil, for example, growers usually sow rainfed soybean in September/October, harvest it and immediately sow rainfed maize, or sometimes only rainfed maize in October, leading to long fallow periods with good rain amounts. Frequently anyhow, there is a blank fallow time between maize harvest and next soybean sowing, although there is not enough time to crop something else during the blank time or not enough natural water conditions for supplying the intermediate crop.

Empirical insights from farmer practices brought the curiosity of growing maize alongside other crop that could be potentially useful. Evidences from Alvim et al. (1989) corroborated by Kluthcouski et al. (2000) about sowing Brachiarias simultaneously with maize showed up the possibility of using this kind of grasses for covering the soil during the blank time, after harvesting corn, and using this sward cover for activities such as grazing, silage production or even keep it to convert in dead cover for subsequent no-tillage systems. As farm intensification processes are inherently associated with higher economical risk, thus the introduction of Brachiaria covering would be able to diversify farm activities and enhance the economical sustainability, besides taking the advantage of possibly using forage in a dry and generally scarce period of rain. Moreover, this process would supposedly reduce weed growing for the following crop, and increase the best maintenance of soil organic matter. Pasture degradation due to erroneous grazing management (i.e. overgrazing) or economic reasons is another existing problem in Brazil. Therefore, if cropping maize is conjugated with Brachiaria, the resulting association could increase either Brachiaria productivity in their following eventual uses as well as farm profitability as a whole in both space and time, given that this kind of consorting has been shown as economically viable (Ceccon, 2007b).

The role of Brachiarias evaluation in this study is to assess pasture establishment for following grassland utilisation. The central objective is to evaluate the establishment of different Brachiaria species under the perspective of intercropping interactions with maize, analysing two Brachiaria sowing dates to identify the potential practical applications in terms of both sowing time and selection of genotype that best suits this kind of agricultural system.

2 Material and methods

2.1 Site description

The field experiment was carried out under centre pivot irrigation on Crop Science Department of University of São Paulo, Piracicaba, Brazil (22º42’30’’ S, 47º30’00’’ W, 550 m altitude), lasting less than a year. Local climate (i.e. Table 1) is humid tropical with three dry months (Cwa – according to Köppen’s classification), whereas local soil is such high fertile clay Rhodudalf, acid and with very low aluminium concentration. Experimental field usually have moderate weed infestation mainly by *Bidens pilosa*, *Emilia sonchifolia Sorghum halepensis*, *Commelina virginica*, *Cyperus rotundus*, *Amaranthus viridis*, *Alternanthera tenella*, and *Ipomoea* spp. In this experiment, the manual weeding was made when maize presented three completely expanded leaves. Therefore, the atrazine (herbicide) application during the initial stages of maize (2 till 6th leaves) had no significant development effect on the *Brachiaria* species studied. In some cases, for example regions with high radiation (between the tropics) or high pressure of weeds, the sub-dose of graminicide, as nicosulfuron can be used to control grasses species or reduce the dry matter accumulation.

Table 1: Average weather data relative to the experiment period (Oct/2003 to Sep/2004); Piracicaba, São Paulo State, Brazil.

Month	Rg	In	Pr	RH	Temperature (°C)			Ev
	(MJ/m^2.day)	(h/d)	(mm)	(%)	Maximum	Minimum	Average	(mm)
Oct/2003	17.68	6.3	89.2	74	30.0	16.3	23.1	5.78
Nov/2003	18.31	6.0	168.0	78	29.5	17.7	23.6	5.57
Dec/2003	19.06	6.4	139.9	84	30.4	19.4	24.9	6.06
Jan/2004	15.51	4.4	196.4	83	29.2	18.7	23.1	4.95
Feb/2004	17.64	6.1	194.0	86	29.6	18.4	24.0	5.93
Mar/2004	17.56	7.1	79.1	83	29.5	17.3	23.4	5.65
Apr/2004	14.84	6.1	92.3	83	29.0	17.1	23.0	4.14
May/2004	11.24	5.0	105.9	89	24.3	12.8	18.6	2.66
Jun/2004	10.78	5.3	49.7	85	24.6	10.7	17.6	2.41
Jul/2004	11.70	5.6	78.4	83	23.8	11.0	17.4	2.65
Aug/2004	16.68	8.0	0.0	65	27.1	10.1	18.6	4.30
Sep/2004	18.60	8.1	7.1	61	32.0	15.3	23.7	5.89

Rg = Global solar radiation; In = Sun bright; Pr = Cumulated precipitation; RH = Relative humidity of air at 7:00 a.m; Ev = Pan evaporation.

2.2 Experimental design and agronomic evaluations

The experimental design was randomised blocks with seven trails and four replications, being each plot composed by four maize rows of 7 m length and spaced 0.7 m each other, totalising 0.1 ha. Brachiarias were sown between rows at 3 kg of pure-viable seeds per hectare. The two central rows were assumed for sampling and the first 0.5 m of each plot extremity was avoided. Above-ground biomasses of Brachiarias were then collected three times throughout maize cycle with a 1.0 m^2 wooded-frame rectangle, 5 cm above soil surface; firstly during maize tasselling; secondly at the maize harvesting. Fifty days after the last sampling, when there was only Brachiarias on field, canopies were uniformly ripped at 7 cm to stimulate tillering and canopy development. The third sampling was done 60 days after maize harvesting, when brachiarias root systems were sampled for all plots by using a 4.5 cm diameter aluminium probe. The probe was positioned at 10 cm from sowing line and closely beside point where above-ground biomasses were collected for the second time. It was considered soil depths at 0 - 20 and 20 - 40 cm, presumably where it concentrates most of root system. Shortly after, root and soil material was washed and sifted in 0.25 mm mash to separate root material, which was dried at 70 ºC for 72 hours. Pictures of intercropping root sampling and establishment are found in Tsumanuma (2004).

The trails are described as: T0) exclusive maize (control); T1) *Brachiaria decumbens* sowed at the same time of maize; T2) *Brachiaria brizantha* cultivar Marandu sowed at the same time of maize; T3) *Brachiaria ruziziensis* sowed at the same time of maize; T4) *Brachiaria decumbens* sowed when maize presented four completely expanded leaves (at maize stage-1, according to phenological classification of Nel and Smit, 1978); T5) *Brachiaria brizantha* cultivar sowed when maize presented four completely expanded leaves (stage 1); and T6) *Brachiaria ruziziensis* sown when maize presented four completely expanded leaves (stage 1).

Soil matric potential was monitored from tensiometer readings aimed at keeping soil as moistened as possible around field capacity water content, so water stresses could be supposedly prevented. Weed suppression done by Brachiarias was evaluated at 60 days after ripening by randomly throwing three times a 0.5 x 1.0 m frame inside each plot. The percentage of control was based on subjective evaluation in comparison to weed green biomass of control plot (exclusive maize), this being considered as zero. This was done to approach the possible effects of Brachiarias on their mean conditions for the subsequent regrowths in terms of plant competition against weeds, as well as to identify the genotypes that would best enhance the following regrowth management and practices in terms of herbicide budgets during the establishment stage.

The statistical procedure was run through Software SAS 9.2 for analysis of variance according to the following model for dry matter root system: $\gamma_{ij} = \mu + \tau_i + \varepsilon_{ij}$; where i=1,2,...,6 and j=1,2,...,4; μ is the average; τ_i is the effect of the ith trial; and ε_{ij} is the error associated to the model, considering $\varepsilon_{ij} \sim N(0,\sigma^2)$. For dry matter of root system, the causes of variation of the model are (degree freedoms in brackets): trials (5); error (15); total (23).

The same procedure was run shoot dry matter and weed suppression, but using the following model: $\gamma_{ijk} = \mu + \tau_i + \beta_j + (\tau\times\beta)_{ij} + \varepsilon_{ijk}$; where i=1,2,...,6; j=1,2,3; and k=1,2,…4; μ is the average; τ_i is the effect of the ith trial; β_j is the effect of the jth level of evaluation factor; $(\tau\times\beta)_{ij}$ is the effect of the interaction of the ith trial and the jth level of evaluation factor; ε_{ij} is the error associated to the model, considering $\varepsilon_{ij} \sim N(0,\sigma^2)$. For dry matter of root system, the causes of variation of the model are (degree freedoms in brackets): trials (5); evaluations (20; interaction between trials and evaluations (10); error (54); total (71).

Both proposed models are proper for multiple comparisons and were used for Tukey's Test at significance level of 5%. The error analysis was run not only for these models but also for the verification of independence assumptions, normality and constant variance as a proof of model validations.

3 Results and Discussion

3.1 Shot dry matter

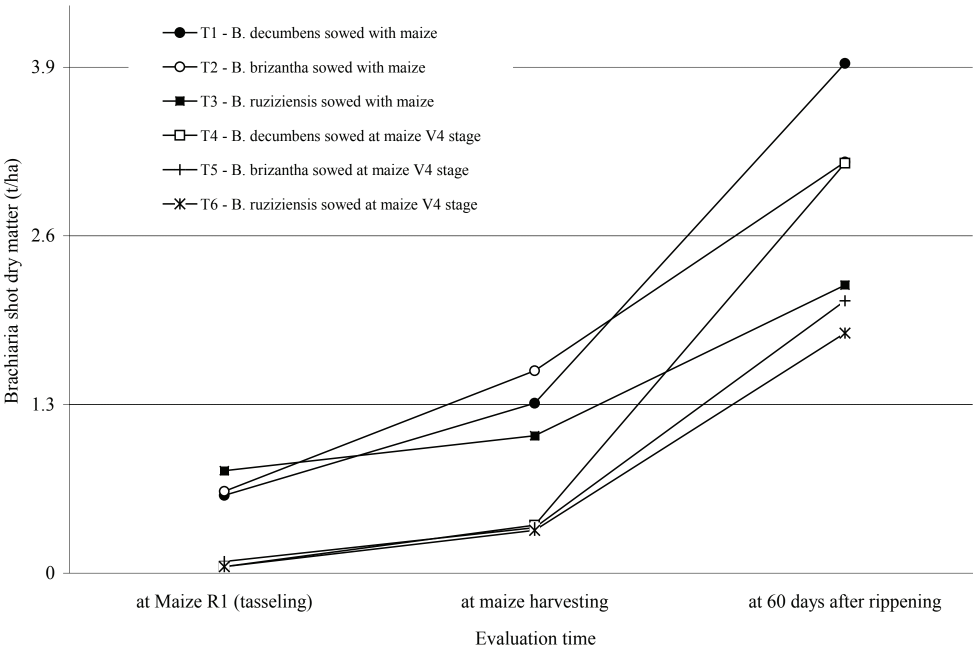
Table 2 shows the shot dry matter of Brachiaria trails at different times of sampling. As expected, no values were obtained for maize sowed exclusively (control plot) as there was no Brachiarias involved, so this trail was omitted. According to Table 2, the initial growth of Brachiarias of trails 4 (T4), 5 (T5) and 6 (T6), which are those sowed when maize was with four leaves completely expanded, were lower than the other trails. This occurrence was kept throughout cycle, as well as for *B. decumbens* and *B. brizantha* cultivar Marandu until the end of the cycle when the third evaluation was performed. As a result, it might be implied that all genotypes evaluated are quite sensitive to maize intercropping competition. Such conclusions corroborate those obtained by Shelton and Humphreys (1972), and Souza Neto (1993).

Table 2: Shot dry matter of Brachiaria trails at different times.

Trail	Shot dry matter (t/ha)		
	at maize tasselling	at maize harvesting	at 60 days after rippening
1	0.60 a B	1.31 a B	3.93 a A
2	0.63 a C	1.56 a B	3.17 ab A
3	0.79 a B	1.06 a B	2.22 bc A
4	0.05 b B	0.37 b B	3.16 ab A
5	0.09 b B	0.35 b B	2.10 bc A
6	0.05 b B	0.33 b B	1.85 c A
Average	0.37 C	0.88 B	2.74 A
CV	37.22	17.79	20.02
DMS	0.31	330.9	1231.9

As a whole, Figure 1 illustrates that higher Brachiaria growth rates were supposedly verified after maize harvesting, certainly as a consequence of both increasing in light interception, reducing competition and tillering processes. The operation of ripening done fifty days after maize harvesting has probably minimised the effect of Brachiaria sowing time on Brachiarias growth. At the third evaluation, *B. decumbens* has shown satisfactorily development (T1 and T4) probably due to the morphological features of this genotype. In terms of total shot dry matter sowed along with maize (T1, T2 and T3), *B. ruziziensis* has statistically differed from both *B. brizantha* and *B. decumbens* at the third evaluation, indicating that the latter genotypes are likely to be more promising, for example, in relation to mulch formation for subsequent immediate no-tillage crop systems. As a result, if the main intention is to establish pasture for good stock acceptability, then *B. ruziziensis* can be surely acceptable as one of the best options, since rain conditions are sufficient to support the grazing processes.

Figure 1: Brachiaria shot dry matter at different times of evaluation.



One important observation is that either trail provided enough conditions for pasture establishment under the maize intercropping perspective, especially when the grasses were sowed at the same time of maize. Although there was no dry matter sampling between tasselling and harvesting, it was noted on field that all Brachiarias have strongly reduced their growth and development after maize, having achieved full cover and before achieved leaves senescence, around stages 7 and 8, after which grasses biomass accumulation apparently restarted with higher rates.

3.2 Root dry matter

The highest absolute root productivity (ton/ha) was verified for Trail 1 (*Brachiaria decumbens* sown at the same time of maize), which also outlined the second highest relative root productivity considering 20 – 40 profiles, besides having achieved the second lowest relative root productivity. Trail 2 (*Brachiaria brizantha* cultivar Marandu sown at the same time of maize) has shown the highest absolute root dry matter from 0 – 40 cm soil depth, which can be explained by the highest and the second highest absolute root system productivities.

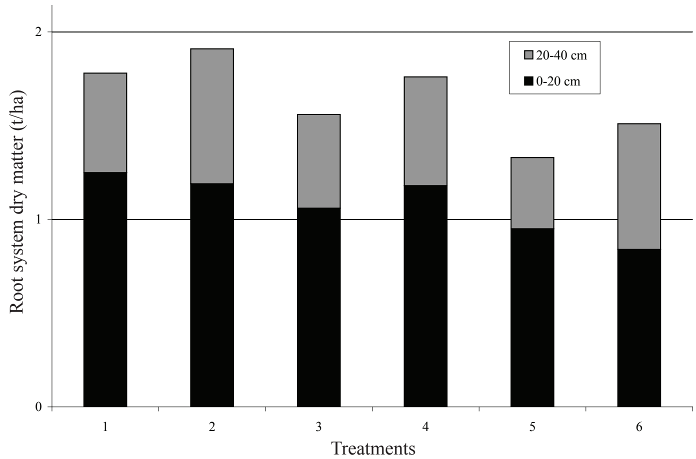
On the contrary, Trail 5 (*Brachiaria brizantha* cultivar sown when maize presented four completely expanded leaves) did not develop satisfactorily as a whole because of low relative root productivities on both soil profiles analysed. Figure 1 shows the root system productivity for all trails.

Interestingly, Trail 6 (*Brachiaria ruziziensis* sown when maize presented four completely expanded leaves) has grown relatively in a balanced way as the lowest and the highest relative root system productivities were observed for 0 – 20 and 20 – 40 cm soil profiles, respectively, albeit the second lowest absolute root system productivity was also observed for this trail, which has provided the lowest difference between root dry matter of both soil profiles evaluated.

None of trails has surpassed 2 ton/ha of root system neither were lower than 1 ton/ha. All root systems analysed has concentrated most of biomass between 0 to 20 cm, representing around 1 ton/ha (~65% of 0 – 40 cm profile) in terms of general average. Broch (2000) has found 76% of root biomass concentrated between 0 and 20 cm. Only Trails 5 and 6 had 0 – 20 cm soil profile absolute root productivities slightly lower than 1 ton/ha.

Considering 0 – 20 cm deep profile, Trail 1 (*Brachiaria decumbens* sowed at the same time of maize sowing) has been statistically different (Tukey's test at 5% significance level) from both Trail 5 (*Brachiaria brizantha* sowed when maize was at stage 1) and 6 (*Brachiaria ruziziensis* sowed when maize was at stage 1). Considering 20 – 40 cm, Trail 5 has differed from both Trail 2 (*Brachiaria decumbens* sowed at the same time of maize sowing) and Trail 6 (Tukey's test at 5% significance level).

Figure 2: Productivity of root system at soil profiles 0 – 20 and 20 – 40 cm.



Considering the sum of both soil profiles, Trail 5 has differed statistically from Trails 1 and 2. Hence, it was evident that the delay in the sowing time of *B. brizantha* cultivar Marandu has slowed down the root system growth and development of this genotype. As seen in Table 2, *Brachiaria brizantha* sown simultaneously with maize (Trail 2) has demonstrated high ability in terms of root system development.

3.3 Percentage of weed control

The effect of Brachiarias on inhibiting weed growth was evaluated after harvesting maize, indicating some practical differences among trials. The plot trial was considered as reference (zero control). Jakelaitis *et al.* (2005) has evidenced that the conventional practices of herbicide application during the initial stages of maize had no effect on final *B. brizantha* establishment. Both the weed biomass and index of weed control of each trial are presented in Table 3.

Table 3: Total biomass dry matter of weeds and the corresponding index of control of genotypes used for establishment 60 days after ripening.

Trail	Weed biomass (kg/ha)	Index of weed control (%)
1	187.07 d	95.27 a
2	704.37 b	77.81 c
3	669.55 b	69.76 d
4	401.32 c	87.29 b
5	733.32 b	65.07 e
6	915.39 a	50.79 f
Average	602	74
CV	9.35	3.01
DMS	129.27	3.43

Both conditions of *B. decumbens* sowing time, with maize and at stage 1 (Trails 1 and 4, respectively) has caused stronger effect on weed control in relation to the other Brachiarias ($P<0.05$; Tukey's test). The effective reduction of weed existence could be probably attributed to the allelopatic effects and abilities of this genotype in compete for production factors such as light, water and soil nutrients (Portes et al., 2000). The sowing date has influenced on weed control in the plots established by *B. brizantha* and *B. ruziziensis*. Trail 6 (*B. ruziziensis* sowed at maize stage 1) has shown the worst effect on weed control along maize rows and sowing lines, which is in agreement with the smallest soil coverage by grasses as a consequence of low regrowth vigour of *B. ruziziensis*. For these cases of Brachiarias, the longer time available for the initial development of Trails 2 and 3 made possible less shading effects and hence better establishment, resulting on better development in comparison to Trails 5 and 6.

3.4 General comments

From forage production viewpoint, all brachiarias that were sown at the same time of maize sowing date have presented similar results. Postponing brachiarias sowing date when maize presented four completely expanded leaves has negatively affected the establishment of all genotypes. For all sowing date trails, only *B. decumbens* has evidenced greater root system development. Both genotypes *B. decumbens* and *B. brizantha* cv. Marandu have demonstrated satisfactory growth conditions after ripening, maybe due to their morphological characteristics to be favourable to regrowth, as suggested by Portes et al. (2000). Additionally, these two species have inhibited weed probably because of their alelopatic features.

It is worthy mentioning that the maize productivity is generally not affected if maize-brachiarias intercropping system is well established and carried out, according to data come from the same field experiment of those of this study (Tsumanuma, 2004). Corroborating to this, Borghi et al. (2006) has varied maize spacing in similar conditions of soil and climate of this study and demonstrated that such intercropping system can be well performed without substantially decreasing the productivity of both species. However, they found higher values for shoot dry-matter of *Brachiaria brizantha* in all trials. Also, the modality of sowing, at the same time, the genotype between maize rows and in the same row of maize has allowed better forage recuperation after maize harvesting (Borghi et al, 2007).

In summary, this study has provided useful data and reinforces that the maize-brachiaria intercropping system has consolidated itself as a new paradigm and challenge in terms of large scale and professional agriculture, although the number of users is still modest. In fact, the state of art is ready to implement (Ceccon, 2007a), but the crucial point will be certainly to turn this system as much operational as possible by developing, from the machinery private industry initiatives, new and feasible technologies to sow maize and brachiarias together, and to apply fertilisers at the same time, or even to sow maize in a conventional way followed by sowing of brachiarias at the moment of first nitrogen fertilisation from one single agricultural machine (i.e. when maize present four fully expanded leaves). From such perspectives, it will be possible to broadly achieve interesting outputs from maize-brachiarias intercropping system.

4 Conclusion

From the perspective of pasture establishment, the genotypes contemplated by this study have provided better productivities when sown at the same time of maize sowing. Genotype *B. decumbens* can be positively highlighted if the purpose is both to produce forage and prevent weeds that can eventually compete against maize crops. In addition, *B. brizantha* is closely similar to *B. decumbens* in terms of production if intercropped with maize during the establishment stages.

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